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Fluids, instabilities and turbulence

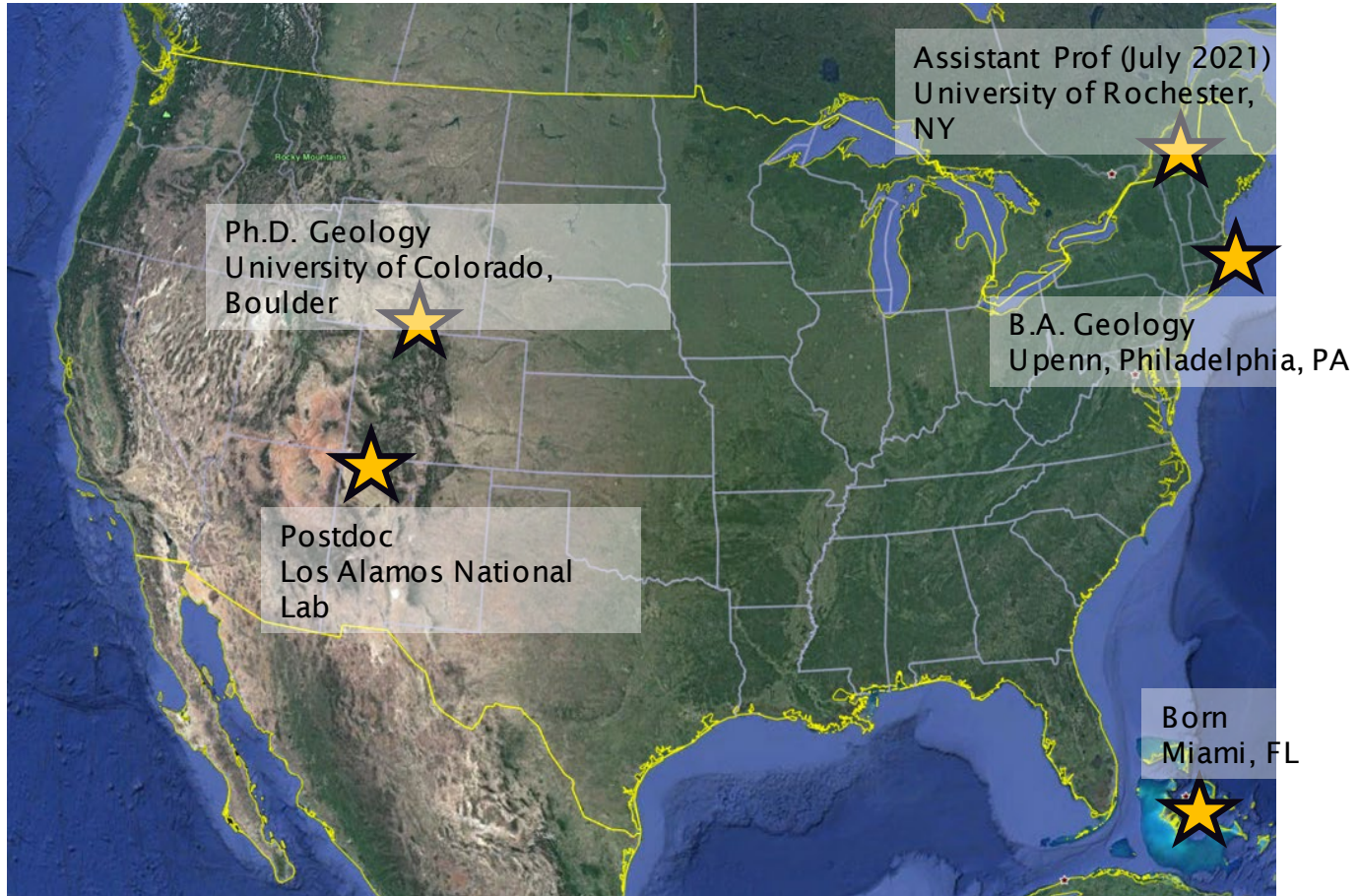
2020 LANL
Summer Camp



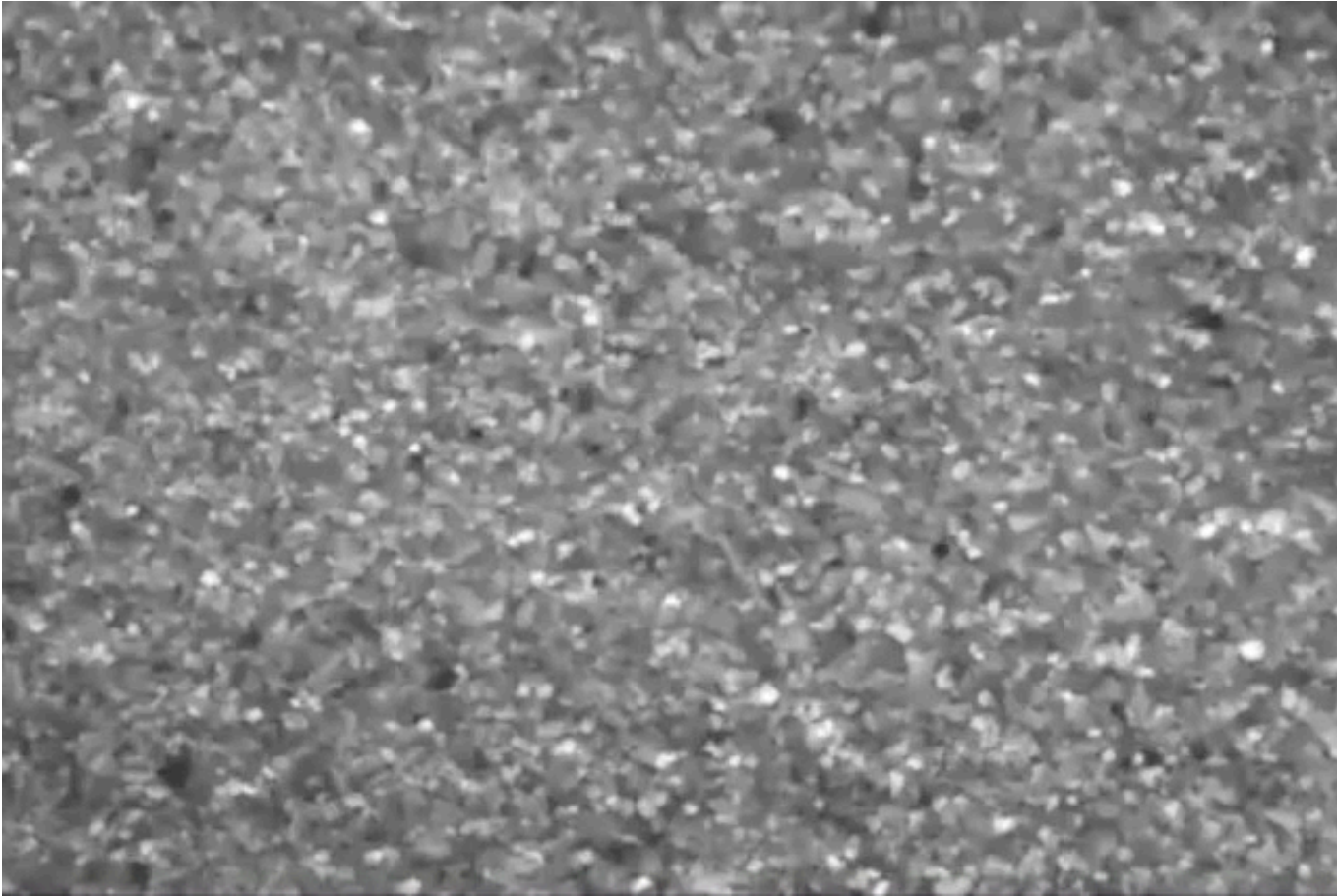
- Tiffany Desjardins
- Rachel Glade
- Dennis Aslangil
- Elizabeth Merritt

About us!

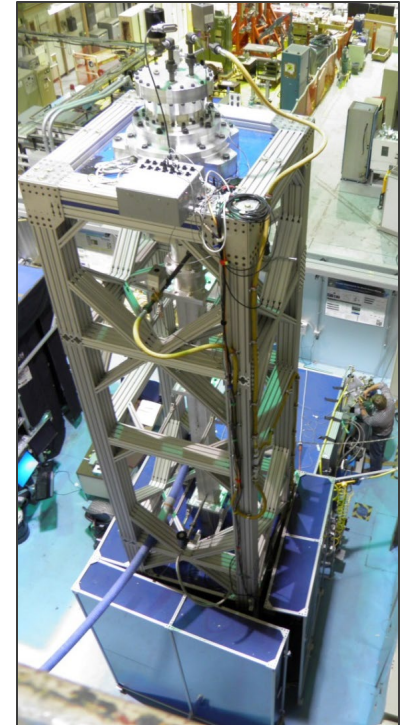
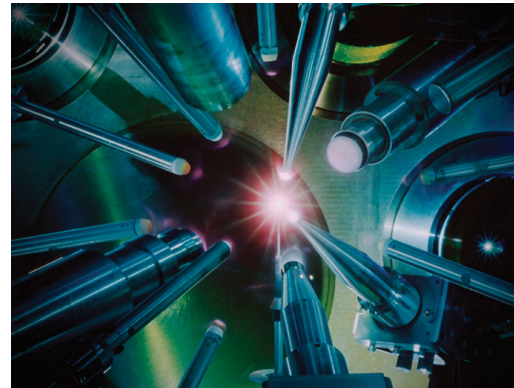
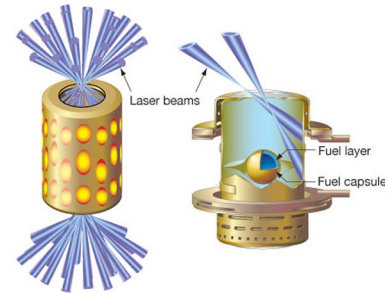
About Rachel Glade...



I study sediment + fluids

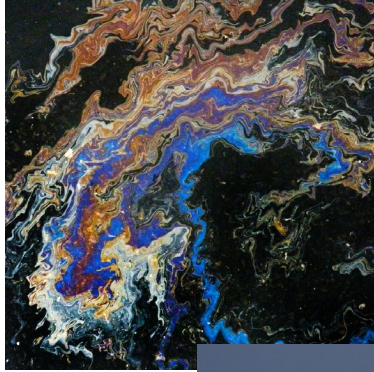


About Tiffany Desjardins....

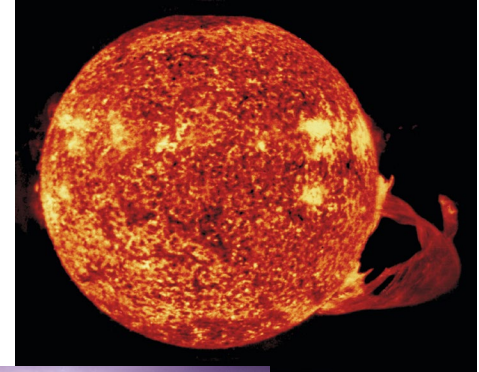
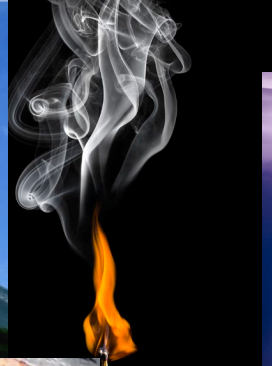
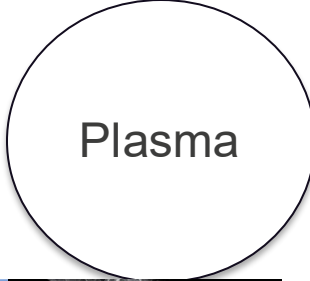
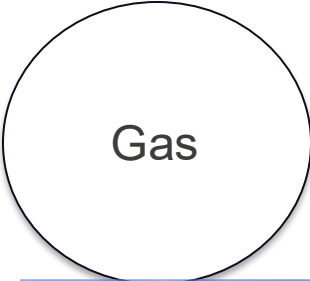
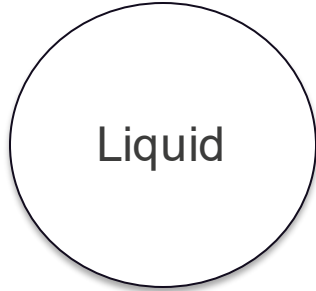


Onto Fluids!

“A fluid is a substance that continually deforms under an applied shear stress or external force”



Oil spill

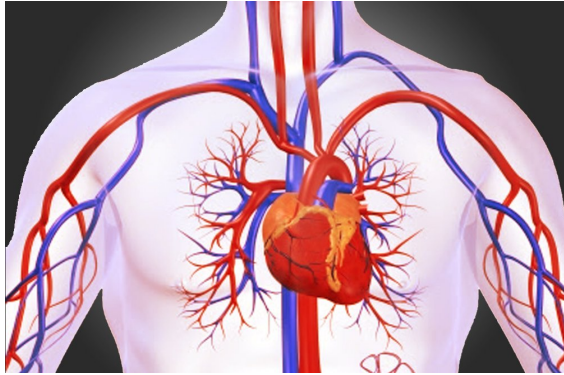


Our Sun

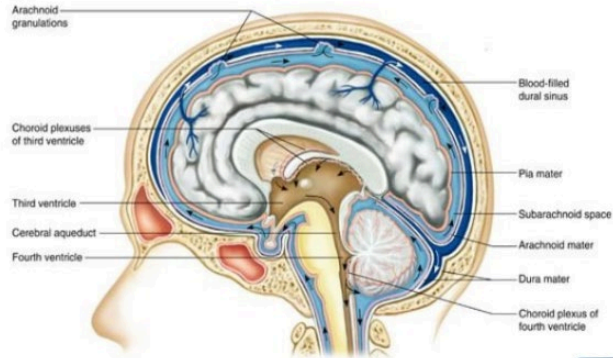


Pause (K)

The study of fluids has a wide range of applications, from medical to environmental and scientific

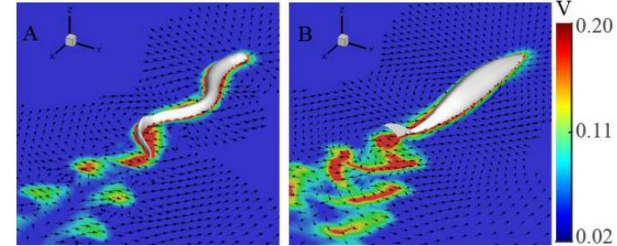


CEREBROSPINAL FLUID (CSF)



Cerebrospinal Fluid (CSF) Processing In Medical Laboratory

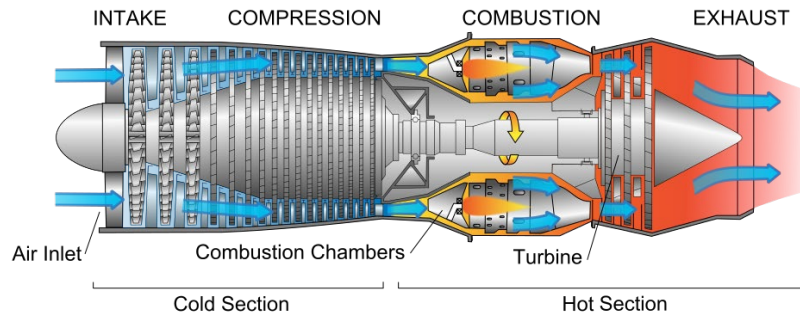
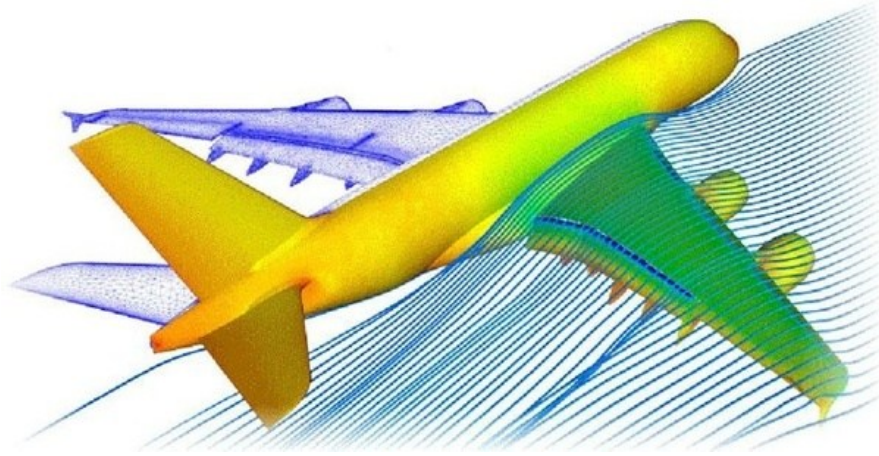
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Robotic fish:

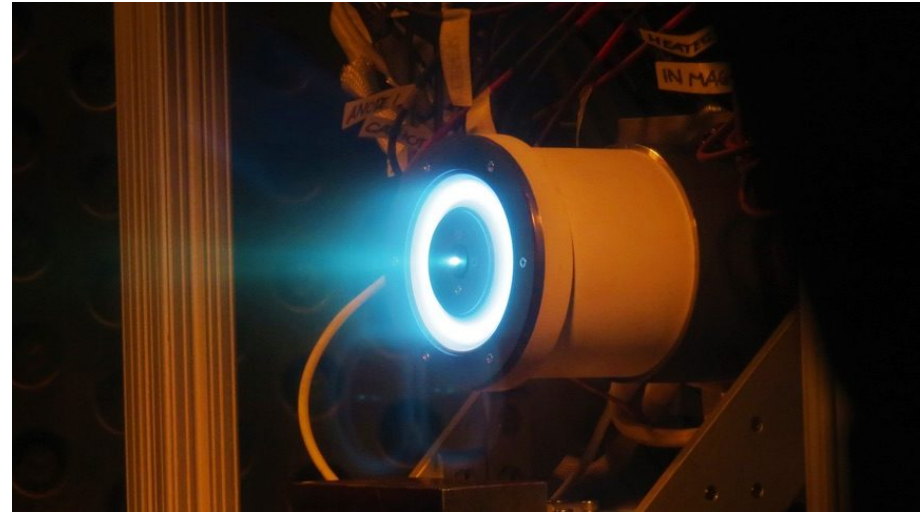
<http://news.mit.edu/2018/soft-robotic-fish-swims-alongside-real-ones-coral-reefs-0321>

The study of fluids has a wide range of applications, from medical to environmental and scientific



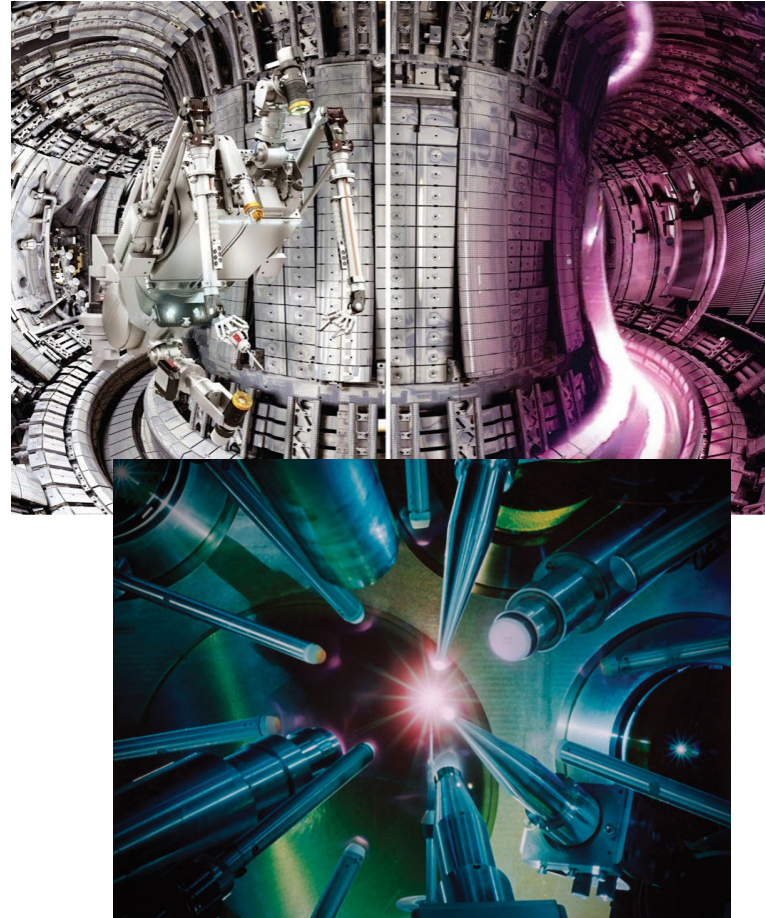
How an aircraft engine works:

<https://www.youtube.com/watch?v=kz5kv0RfeUc>



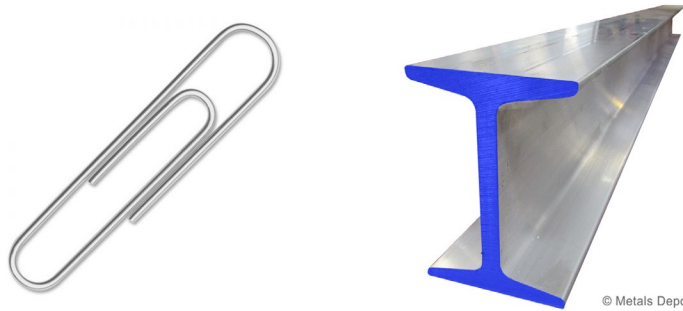
Plasma thrusters are developed for engines on space craft

The study of fluids has a wide range of applications, from medical to environmental and scientific



What are important properties of a fluid?

- **Density**: measure of 'compactness', it is the ratio of mass to volume
 - **Example**: a paper clip and a steel beam have the same density but a steel beam is much heavier



- Density is decided by amount of space between atoms
 - Gases have more space than liquids, and therefore have a lower density

Important fact: Higher density fluids sink while lower density items float



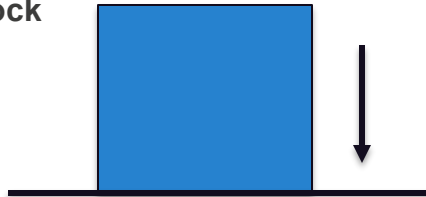
What are important properties of a fluid?

- **Pressure**: measure of force on an area, $P = \frac{\text{Force}}{\text{Area}}$

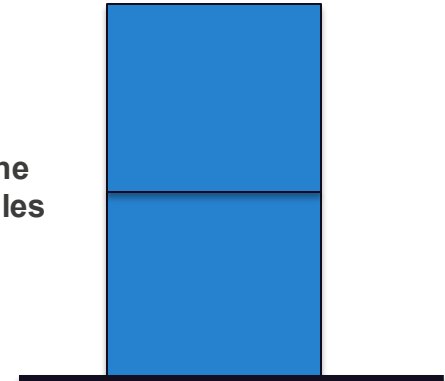
Consider a single block sitting on table:

Gravity causes the block to push on the table

We can quantify the amount of 'push' as pressure



If we put a second identical block on top the first, the pressure doubles



What are important properties of a fluid?



Hot air balloons heat the air, causing it become lighter than surrounding colder air; since the light fluid 'floats' on the heavy, the balloon can be lifted from the ground

- **Temperature:** measure of heat, or how fast molecules are vibrating
 - Temperature can affect the density or pressure of a fluid
 - **Example:** Hot water is less dense than cold water



When you boil water, the hot water at the bottom rises to the top

The bubbles come from air released from the hot water; since air is lighter, the bubbles rise to the surface as well

Density, pressure and temperature are related by the *ideal gas law*

Pressure x Volume = constant x number of atoms x Temperature
= constant x density x Temperature

$$P = R\rho T$$

Peeps in a Vacuum chamber:

https://www.youtube.com/watch?v=fxLY1SGXV_E

Mr. Wizard and a Vacuum pump:

<https://www.youtube.com/watch?v=MYAmPRQ4eWo>

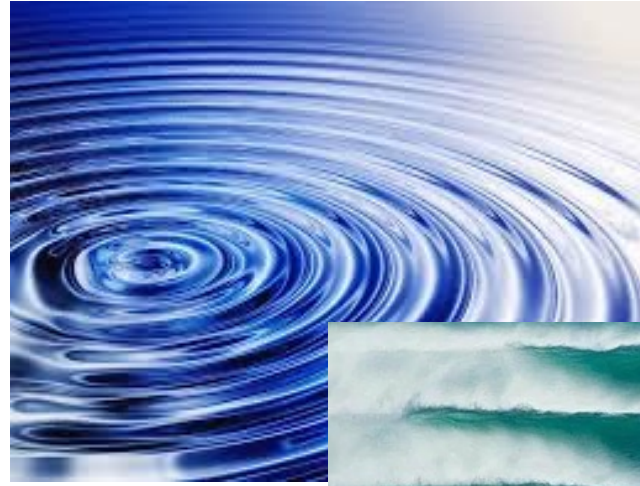
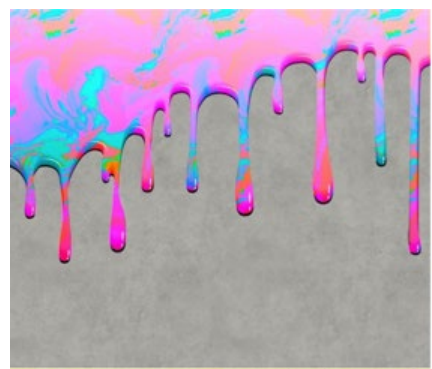
For more information on fluids and types of experiments, check out:

<https://fyfluidynamics.com/>

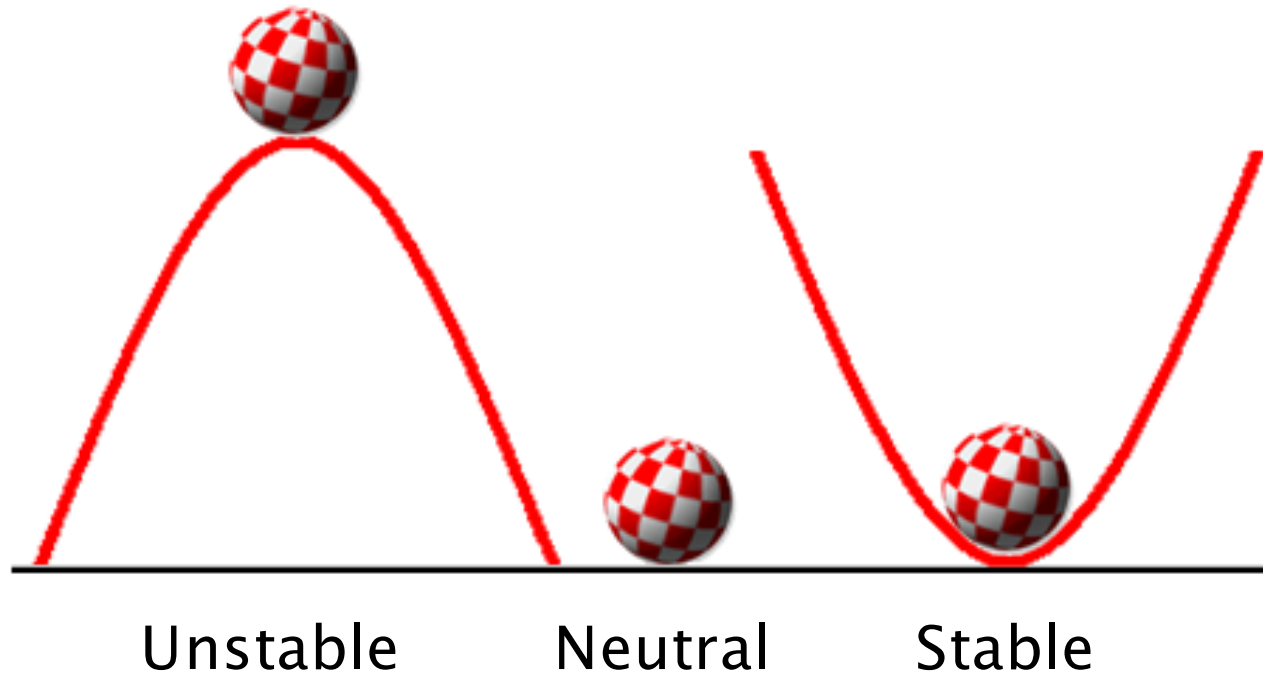
Fluid Patterns & Instabilities



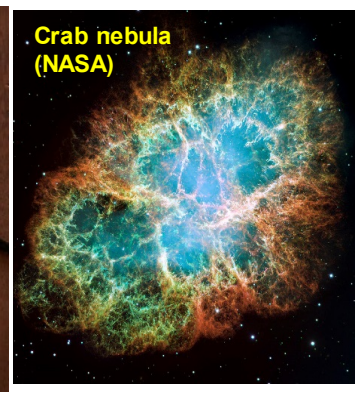
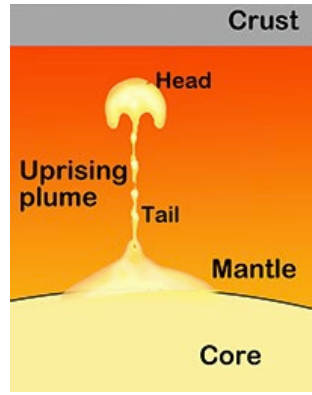
Fluid instabilities occur naturally and are important for understanding how fluids move and mix



What is an instability?

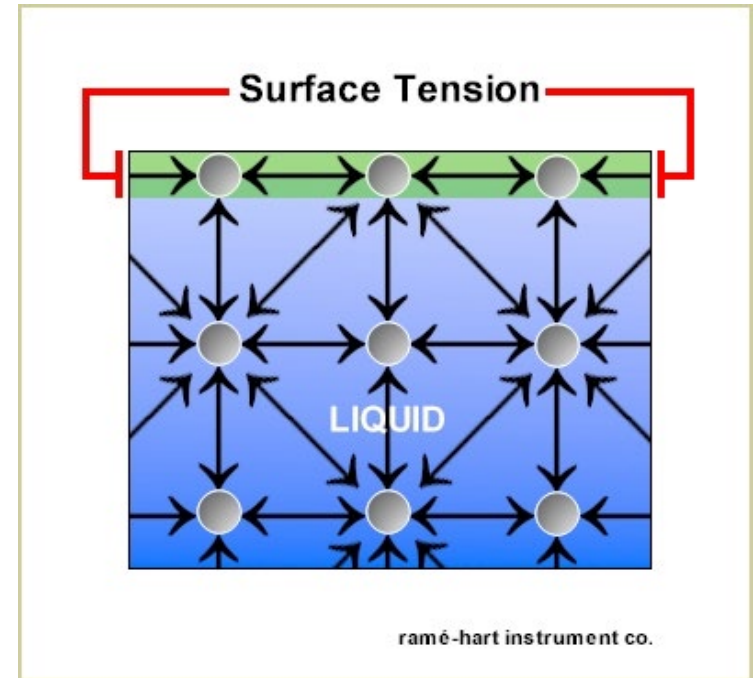


Fluids instabilities are a natural phenomena that occur across many physical regimes



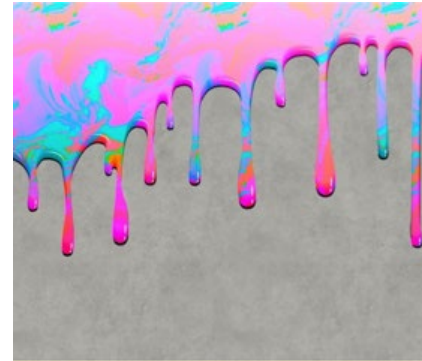
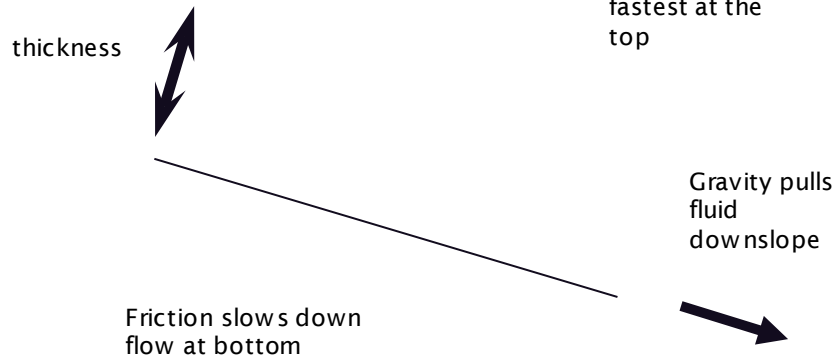
Can anything prevent instabilities from occurring?

What is surface tension?



Competition between gravity and surface tension leads to 'fluid fingers' in these images

1. At fluid front, surface tension holds back flow, causing it to thicken
2. Thicker flow moves faster
3. Small variations in thickness lead to growth of "fingers"

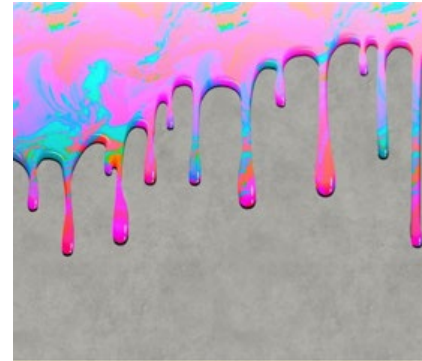


Competition between gravity and surface tension leads to 'fluid fingers' in these images

This can be expressed mathematically:

$$\lambda \sim H \left(\frac{3\mu U}{\sigma} \right)^{-1/3}$$

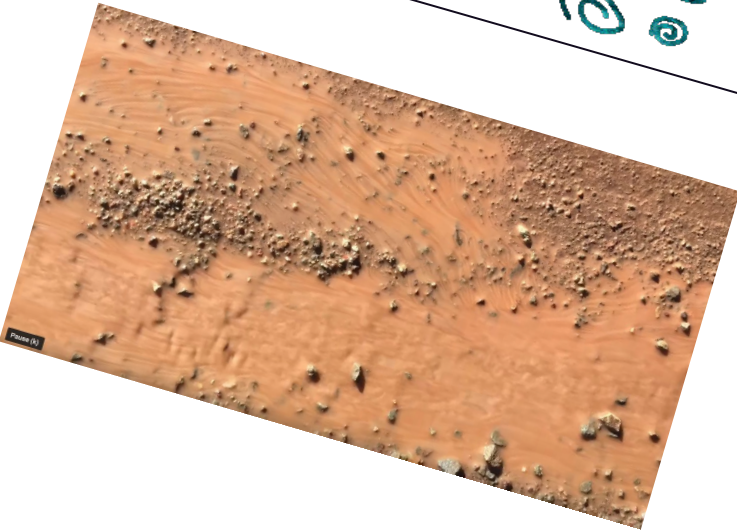
Wavelength λ is indicated by an arrow pointing to the symbol λ .
Thickness H is indicated by an arrow pointing to the letter H .
Viscosity μ is indicated by an arrow pointing to the symbol μ .
Velocity U is indicated by an arrow pointing to the symbol U .
Surface tension σ is indicated by an arrow pointing to the symbol σ .



What is turbulence?

Schematic

Laminar flow – **transition** – **turbulence**
Smooth and regular; Chaotic and irregular



In nature

Laminar flow



Turbulent flow



Short history of turbulence

Mathematical Description: The Navier-Stokes Equations
by

French engineer Claude-Louis Navier

&

British physicist and mathematician Sir George Gabriel Stokes
Late 19th Century

Van-Gogh Dutch Painter (1853-1890)

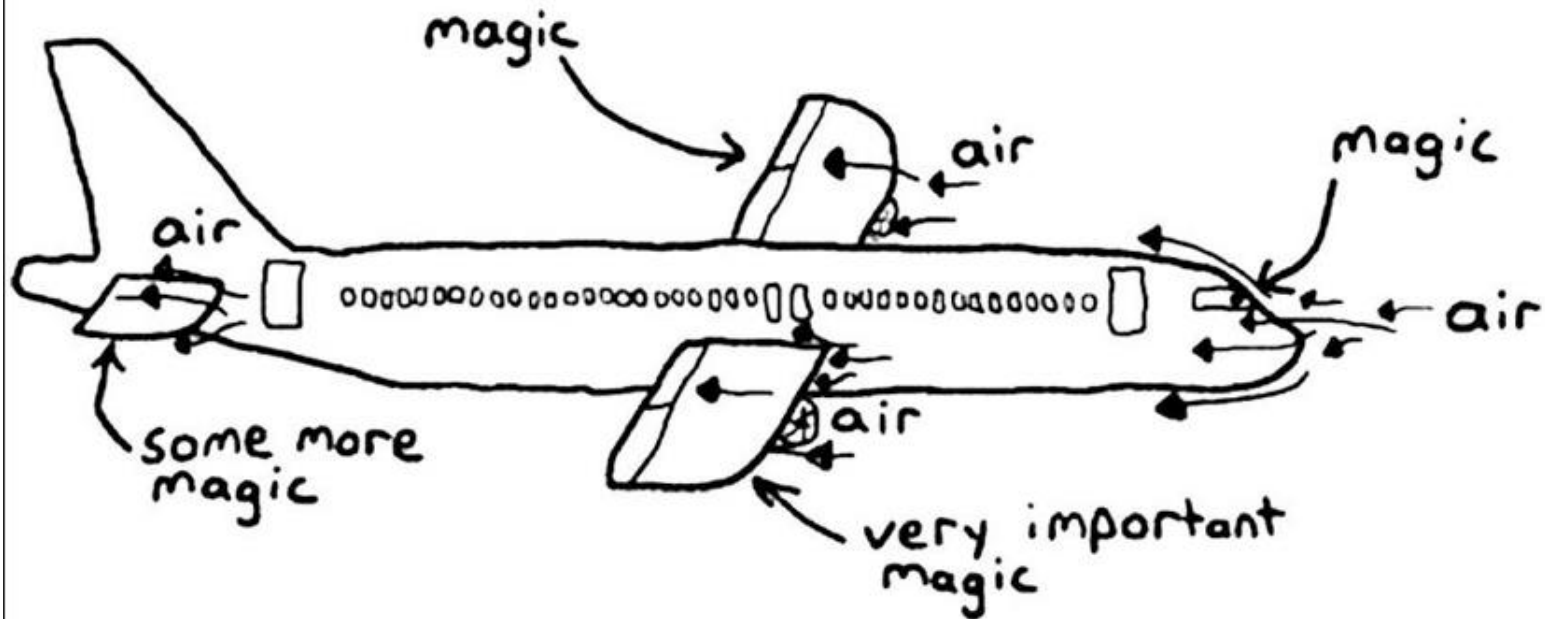


“turbulence” & “turbulent flow” terms are
used in the early 20th century.

Not fully understood yet!

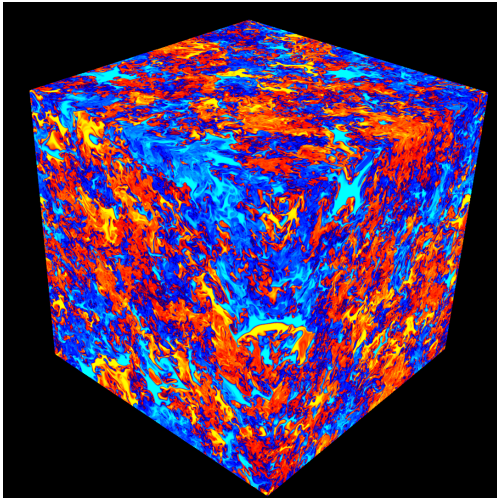
Why it is important?

how planes fly



The study of fluids is multi-disciplinary: it takes many methods to unlock the physics

Numerical Simulations



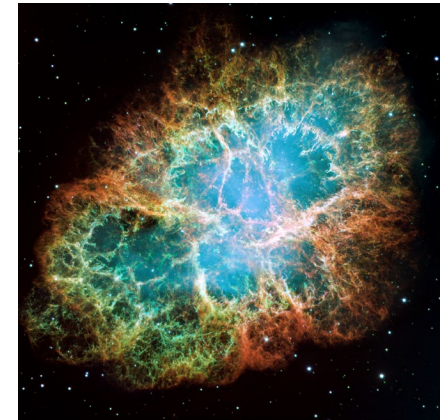
<https://youtu.be/N5OAVgl4Ak4>

Experiments



https://youtu.be/_UoTTq651dE

Observation



What we (scientists and engineers) try to do?

Find the ground truth by observations, experiments, and mathematics.

- Very expensive process,
- takes years.

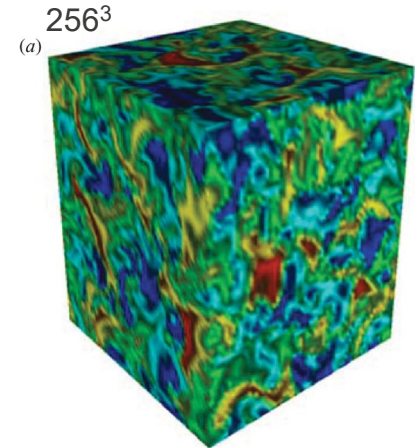
Engineering models

- Less expensive process,
- less accurate,
- takes hours.

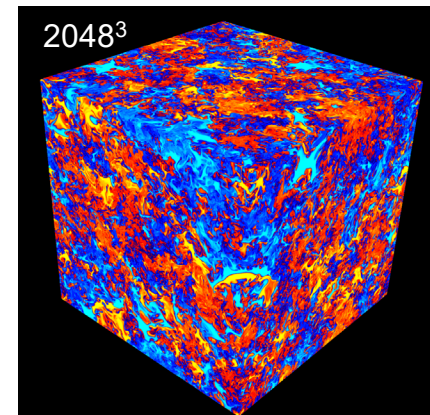
Applications

- Aerospace industry
- Astrophysics
- Weather forecasting
- Energy from Fusion

Last decade¹



Current decade²



¹Livescu, D., and Ristorcelli, R., "Buoyancy-driven variable-density turbulence." *J. Fluid Mech.*, **591**, 43–71 (2007).

²Aslangil, D., Livescu, D., and Banerjee, A., "Effects of Atwood and Reynolds numbers on buoyancy-driven homogeneous variable-density turbulence." *J. Fluid Mech.*, **485**, A12 (2020).

Experiment Time!
